Top-Down, Intelligent Reservoir Modeling (TDIRM): An Alternative Reservoir Modeling Technique; Integrating Classic Reservoir Engineering with Artificial Intelligence & Data Mining Techniques*

Shahab D. Mohaghegh[1]

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[1]Petroleum & Natural Gas Engineering, West Virginia University, Morgantown, WV (mailto:shahab@wvu.edu)

Abstract

Traditional reservoir simulation and modeling is a bottom-up approach. It starts with building a geological model of the reservoir, adding engineering fluid flow principles to arrive at a dynamic reservoir model. The dynamic reservoir model is calibrated using the production history of multiple wells and the history matched model is used to strategize field development in order to improve recovery.

Top-Down full field subsurface modeling approaches the reservoir simulation and modeling from an opposite angle by attempting to build a realization of the reservoir starting with well production behavior (history). The production history is augmented by core, log, well test and seismic data in order to increase the accuracy and fine tune the Top-Down model. The model is then calibrated (history matched) using the most recent wells as blind dataset.

Although not intended as a substitute for the traditional reservoir simulation of large, complex fields, this innovative and novel approach can be used as an alternative (at a fraction of the cost) to traditional reservoir simulation in cases where performing traditional modeling is cost (and man-power) prohibitive. In cases where a conventional model of a reservoir already exists, Top-Down modeling should be considered as a complement to, rather than a competition for the traditional technique. It provides an independent look at the data coming from the reservoir/wells for optimum development strategy and recovery enhancement.

Top-Down Modeling is an elegant integration of state-of-the-art in Artificial Intelligence & Data Mining (AI&DM) with solid reservoir engineering techniques and principles. It provides a unique perspective of the field and the reservoir using actual measurements. It provides qualitatively accurate reservoir characteristics that can play a key role in making important and strategic field development decisions.

In this article, principles of Top-Down modeling are discussed along with an actual case study. Furthermore, validation of the top-down model using traditional simulation and modeling will also be presented and discussed.

Top-Down, Intelligent Reservoir Modeling (TDIRM)

An Alternative Reservoir Modeling Technique; Integrating Classic Reservoir Engineering with Artificial Intelligence & Data Mining Techniques

Shahab D. Mohaghegh, Ph.D.
Petroleum & Natural Gas Engineering
West Virginia University

2009 AAPG Annual Conference, Denver, Colorado

Outline

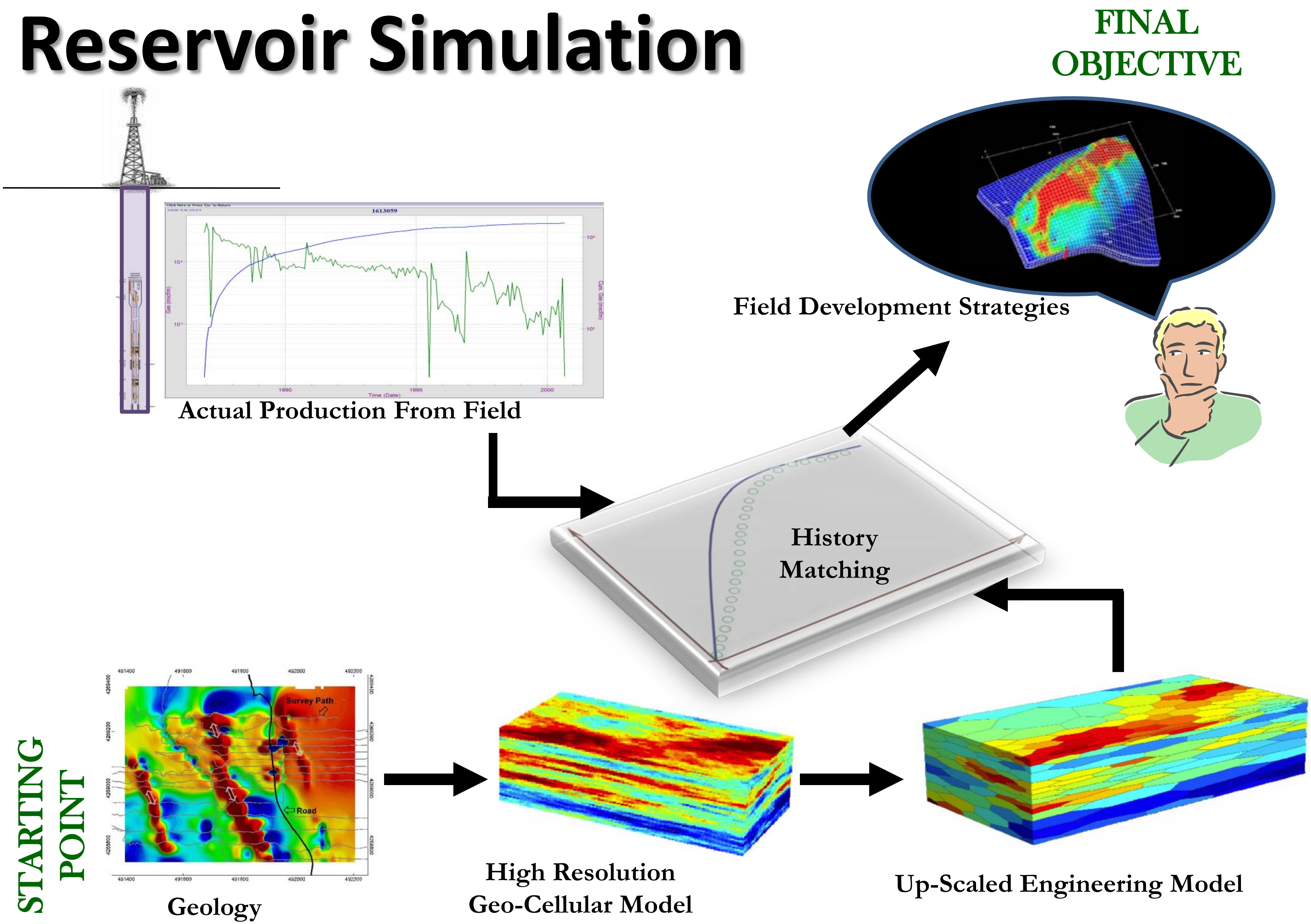
- Definition of TDIRM
- Advantages & Disadvantages of TDIRM
- TDIRM Data Requirement
- Development Steps
- Results
- Conclusions

Top-Down, Intelligent Reservoir Modeling (TDIRM)

Definition

- A **full-field, cohesive model** of fluid flow in the hydrocarbon reservoir, developed **based on production behavior** of multiple wells and by **integrating reservoir engineering** principles with state-of-the-art in Artificial Intelligence and Data Mining **(AI&DM)**.

Reservoir Simulation

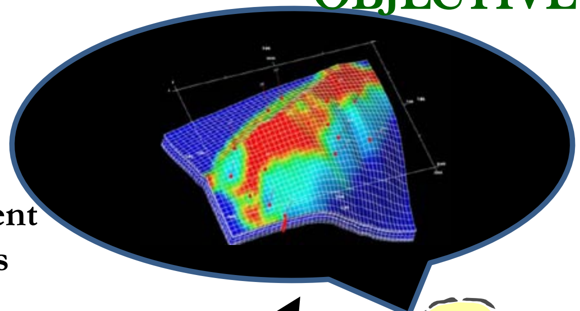


Top-Down Modeling

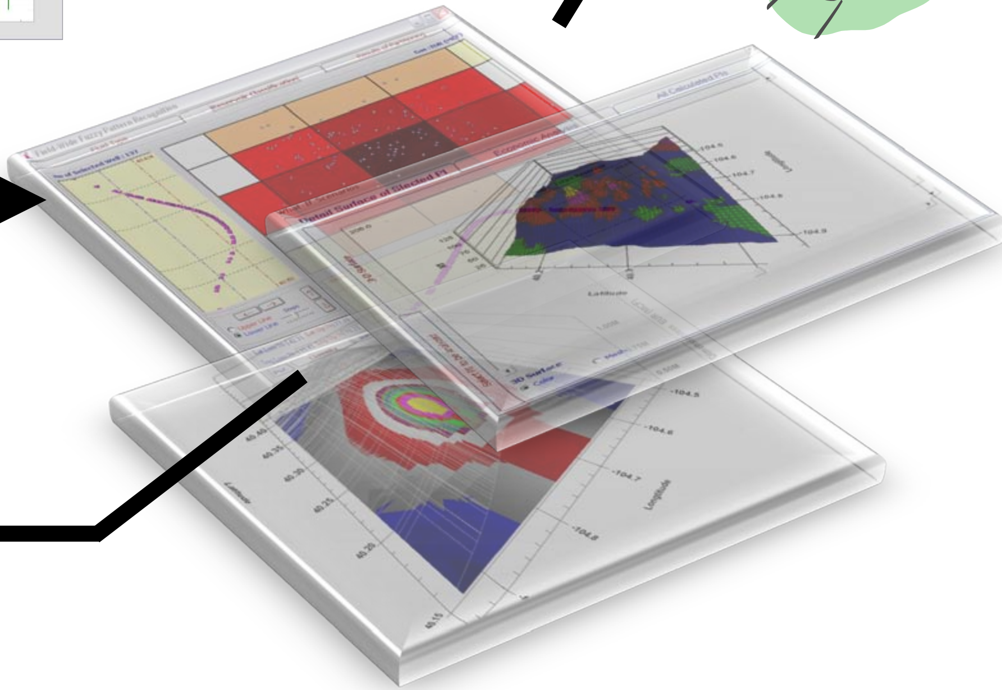
STARTING POINT

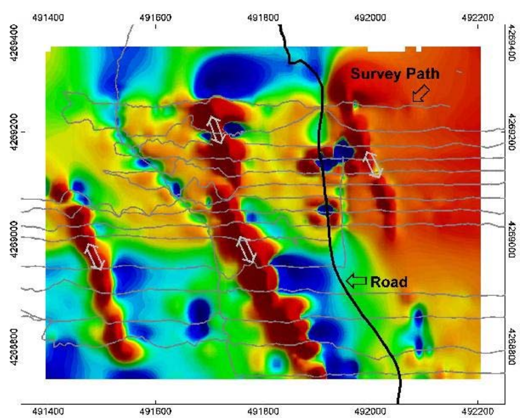
Actual Production From Field

FINAL OBJECTIVE



Field Development Strategies





Geology

Outline

- Definition of TDIRM
- Advantages & Disadvantages of TDIRM
- TDIRM Data Requirement
- Development Steps
- Results
- Conclusions

Advantages of TDIRM

- **Data Requirement**
  - Production Rate History
  - Well Logs
- Other data can be used to refine the model
  - Core data
  - Well Test
  - Pressure history
  - Seismic
  - …

Advantages of TDIRM

- **Development Time**
  - Weeks Rather than months/years
- **Analysis Complexity**
  - Does not require a Ph.D. or extensive training
- **Usage & Utility**
  - Alternative to conventional simulation
  - Complement to conventional simulation

Advantages of TDIRM

- **Technology**
  - Geology
  - Reservoir Engineering
  - Artificial Intelligence and Data Mining
- **Deliverables**
  - Full Field Model
  - Remaining Reservoirs
  - Infill Locations
  - Underperformer Wells

Disadvantages of TDIRM

- TDIRM is not applicable to new fields with little production history.
- Application of TDIRM is not recommended to fields with less than 50 wells and less than 5 years of production history.

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Minimum Data Requirement

- Production History
  - Production rate history
  - Well locations
  - …

Minimum Data Requirement

- Well Logs
  - Porosity
  - Formation Thicknesses (Net/Gross)
  - Initial Water Saturation
  - Formation tops
  - …

Other Data

- Following data can be used in the TDIRM
  - Geological Interpretations
  - Core data, Core Analysis
  - Well Tests
  - Pressure data
  - Seismic data
  - …

Top-Down, Intelligent Reservoir Modeling

- In top-down modeling we start from production data and try to deduce a picture of fluid flow in the reservoir.
- Once the picture is formed (and validated) it is used in order to plan for the future and make strategies for field development.

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- Definition of TDIRM
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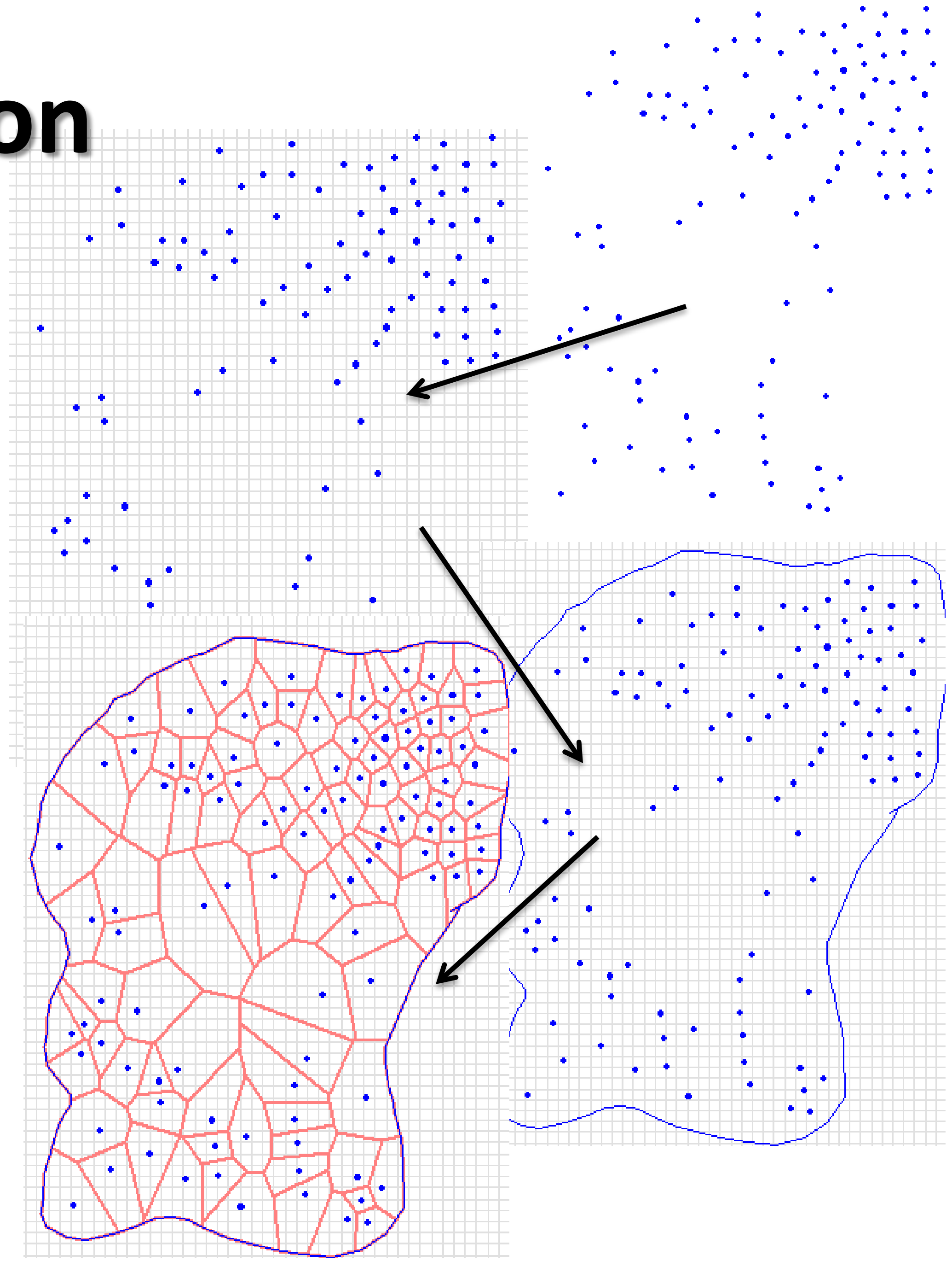
- TDIRM Data Requirement
- Development Steps
  - Single-well Modeling (calssic Reservoir Eng.)
  - Fuzzy Pattern Recognition
  - Predictive Modelind
- Results
- Conclusions

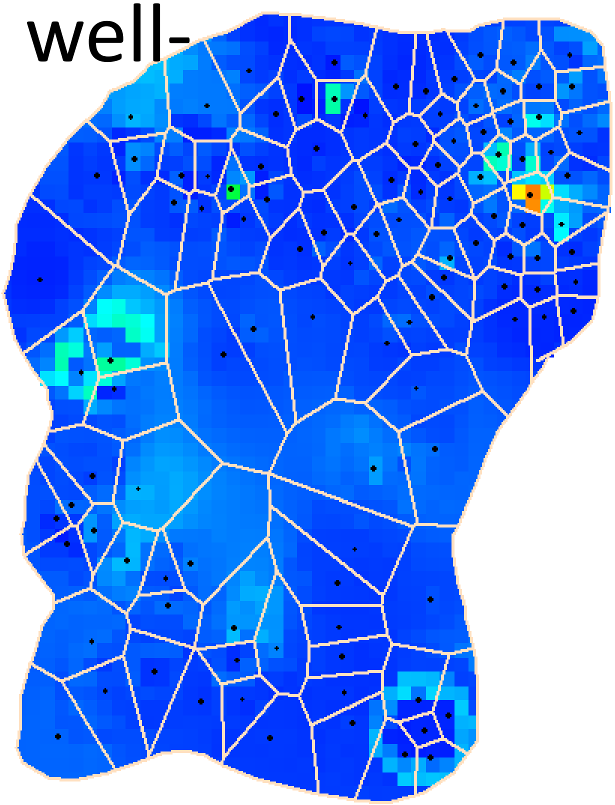
Field Information

- Well locations.
- Cartesian Grid.
- Outer boundary (structure map).
- Estimated Ultimate Drainage Area (EUDA) using Voronoi cells.



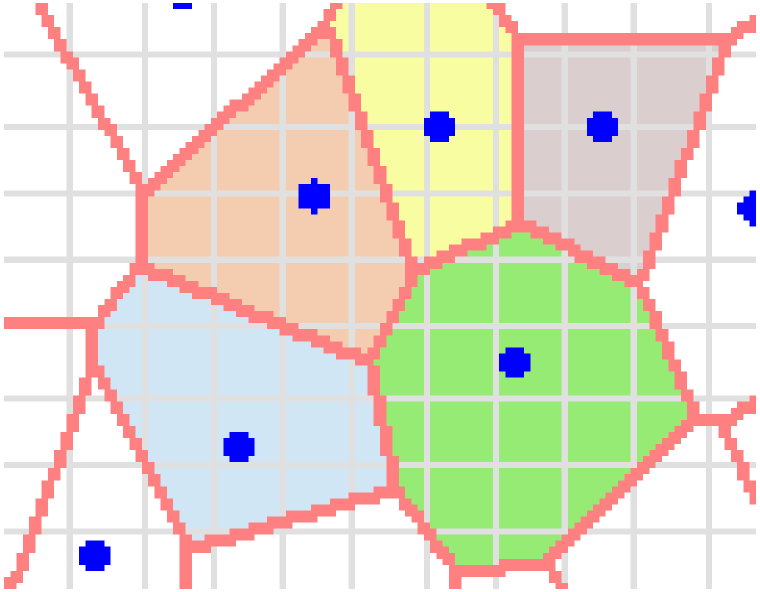
Field Information

- Using geo-statistics (kriging, co-kriging and/or Sequential Gaussian Simulation - SGS) the Cartesian grid is populated with well-based data.
- Thickness, Porosity, Saturation, etc.



Grid Association

- Each Voronoi (EUDA) cell include multiple Cartesian grids.
- Well-based characteristics are averaged over entire Voronoi (EUDA) cell.



Production Data Analysis

- Starting with Production data
  - Decline Curve Analysis
  - Type Curve Matching
    - Removing Subjectivity & making the analysis repeatable.
  - History Matching
    - Single Well Radial numerical simulation
  - Volumetric Reserve Calculation
  - Recovery Factor Estimation

Data Collected and Generated

- Spatio-temporal Data Collected (generated):
  - 150 wells - ***150***
  - Location, Lat., Long. , Depth ***(3)*** – ***450***
  - Porosity, Thickness, Saturations, ***(3)*** – ***1,350***
  - EUDA, RF, IGIP, ***(3)*** – ***4,050***
  - Permeability, Fracture Half-Length, ***(2)*** – ***8,100***

An Example

Data Collected and Generated

- Data Collected in Time:
  - 10 Years of Monthly Production Rates, ***(120)*** – ***972,000***
  - Qi, Di, b, ***(3)*** – ***2,916,000***
  - 3, 6, 9, Months Cum. productions and 1, 3, 5 and 10 years Cum. productions and 30 Year EUR, ***(8)*** – ***23,328,000***

An Example

Data Collected and Generated

- Same type of information for the 3 to 5 Closest Offset Wells (impacting the production of each well):
  - In Case of 3 Closest Offset Well, ***(3)*** – ***69,984,000***
  - In Case of 5 Closest Offset Well, ***(5)*** – ***116,640,000***

An Example

Data Collected and Generated

- A small to moderate field produced more than ***116,640,000*** pieces of spatio-temporal data.
- A fairly large field (350 Wells) with about 20 years of production will generate a spatio-temporal database with ***793,800,000*** pieces of data.

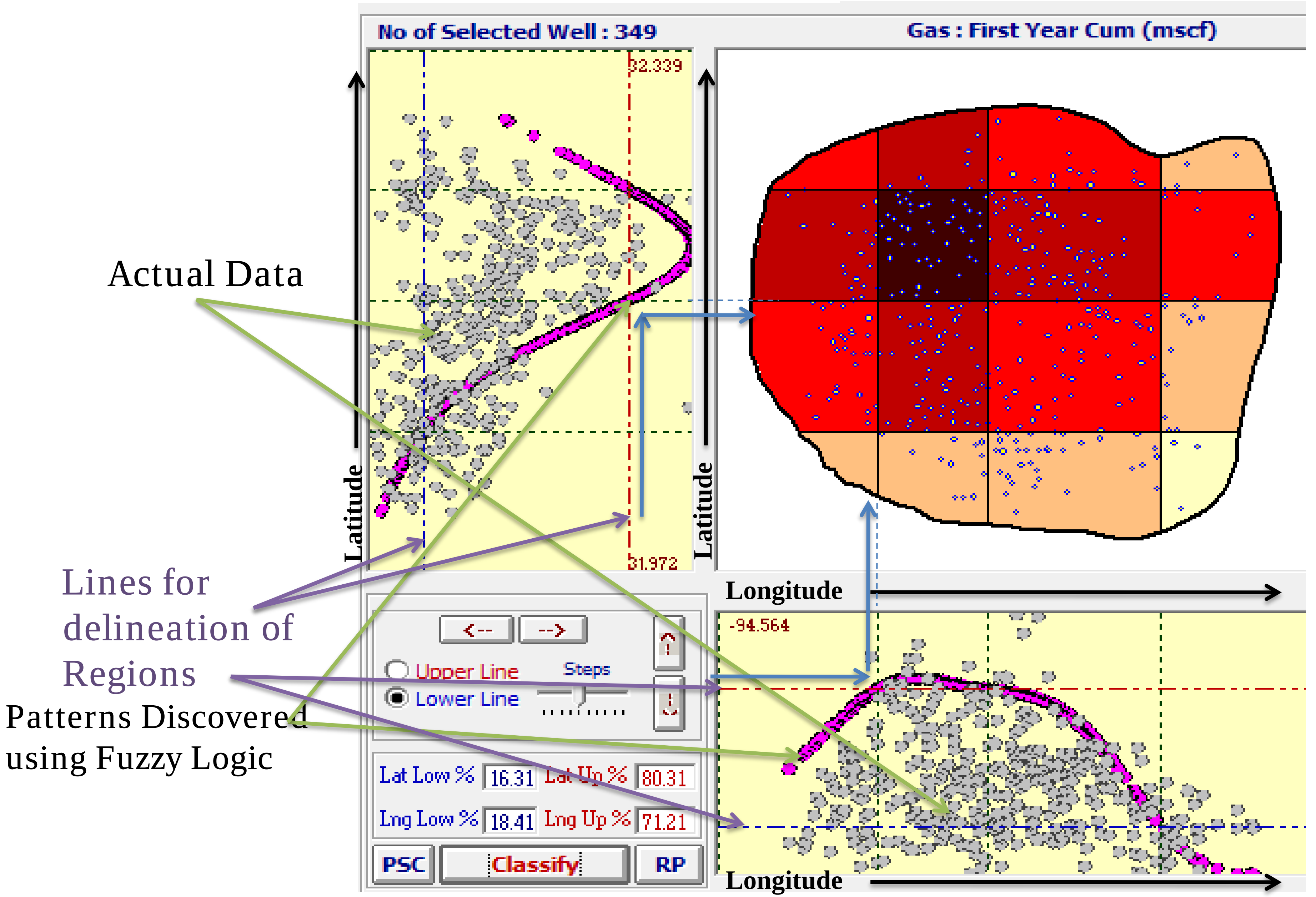
Lets mine this data in order to discover some valuable patterns.

An Example

Fuzzy Pattern Recognition

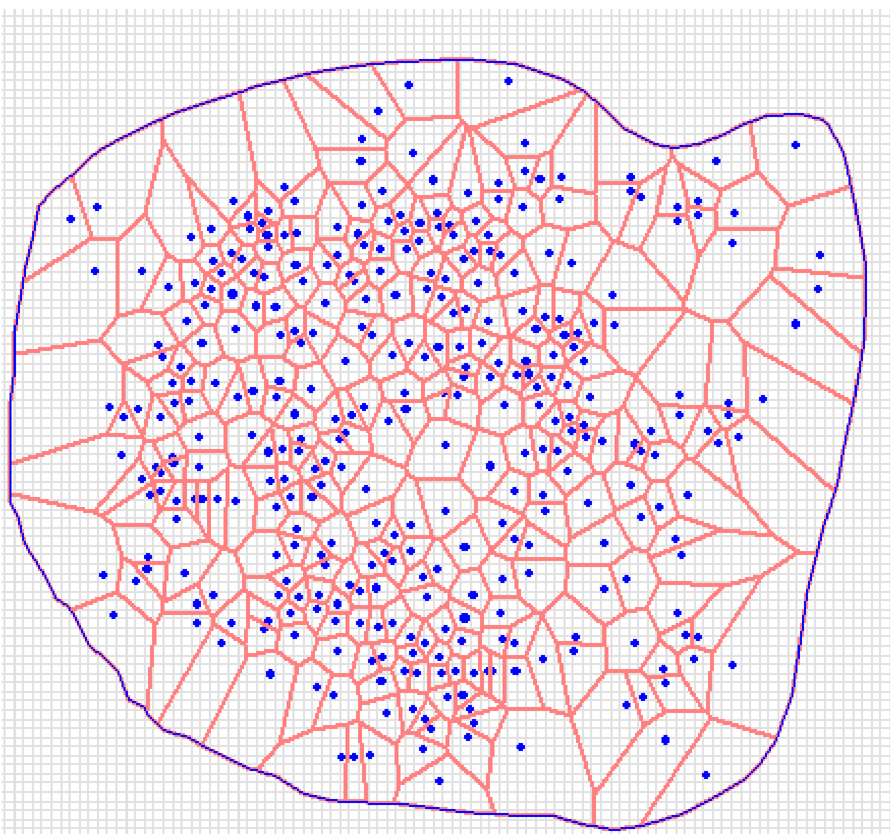
- Objective:
  - Identify the sweet spots in the field.
  - Identify the underperformer wells.

- Sweet Spots represent:
  - Remaining reserves.
  - Locations for infill drilling with high probability of success.



No of Selected Well : 349
Gas : First Year Cum (mscf)
32.339
31.972
Latitude
Latitude
Longitude
Longitude
-94.564
Actual Data
Lines for delineation of Regions
Patterns Discovered using Fuzzy Logic
<--
-->
Upper Line
Lower Line
Steps
Lat Low % 16.31
Lat Up % 80.31
Lng Low % 18.41
Lng Up % 71.21
PSC
Classify
RP

Fuzzy Pattern Recognition



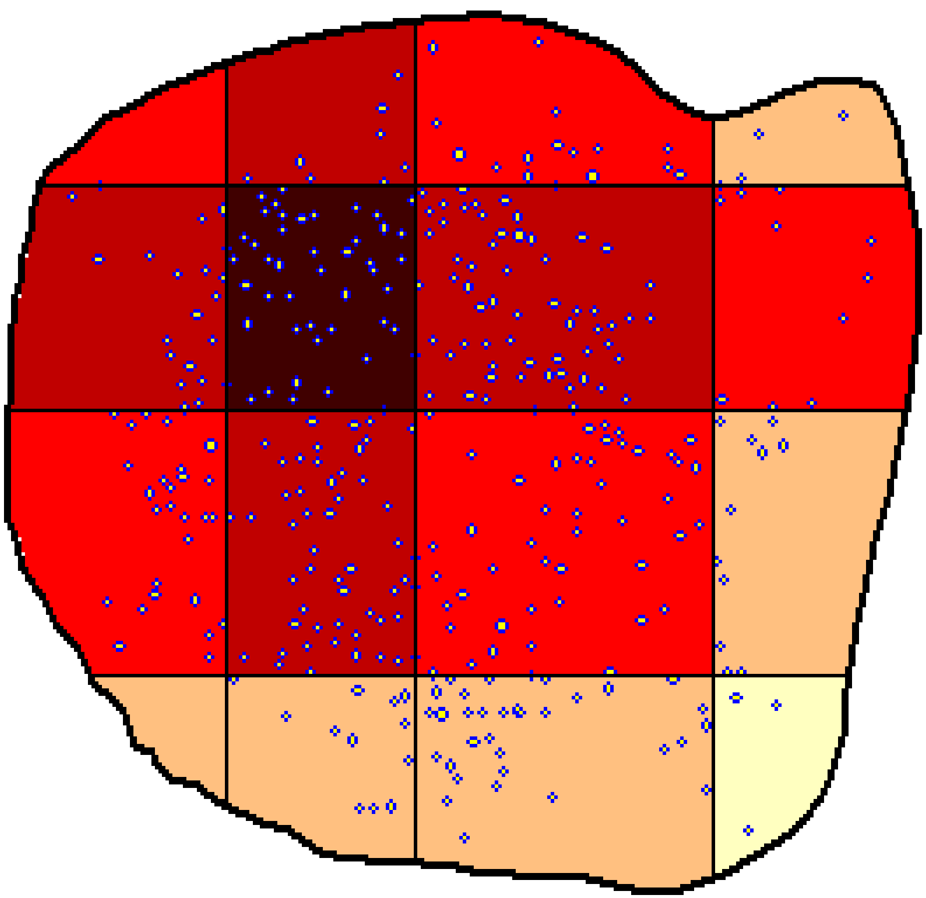
Field-Wide Fuzzy Pattern Recognition

Features for Analysis | Pattern Recognition

Current Zone : Entire Reservoir

Partition Type	RRQI	First Year Cum (mscf)-Gas		
		Avg. Value	# Wells	% Wells
High-High	1	583,954.556	45	12.89
High-Mid	2	375,704.359	142	40.69
High-Low & Mid-Mid	3	295,810.800	100	28.65
Mid-Low	4	211,609.288	59	16.91
Low-Low	5	122,354.000	3	0.86
Total Wells			349	100

Fuzzy Pattern Recognition



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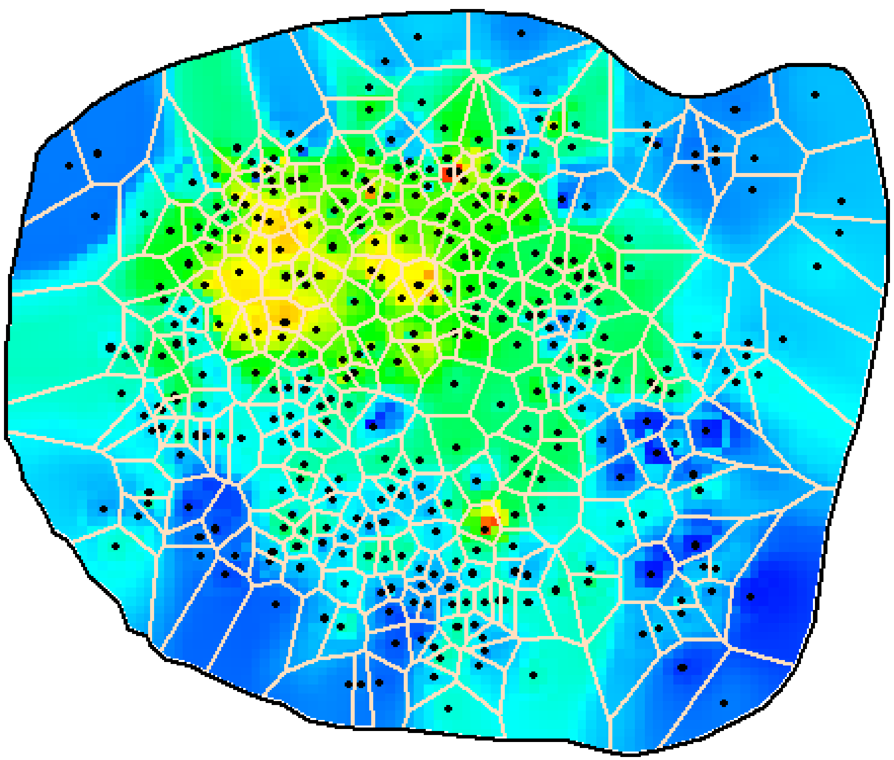

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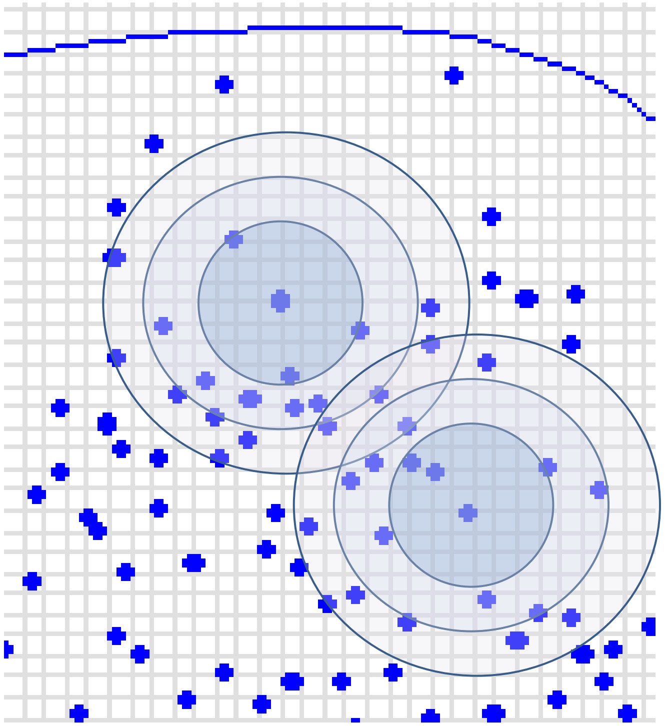
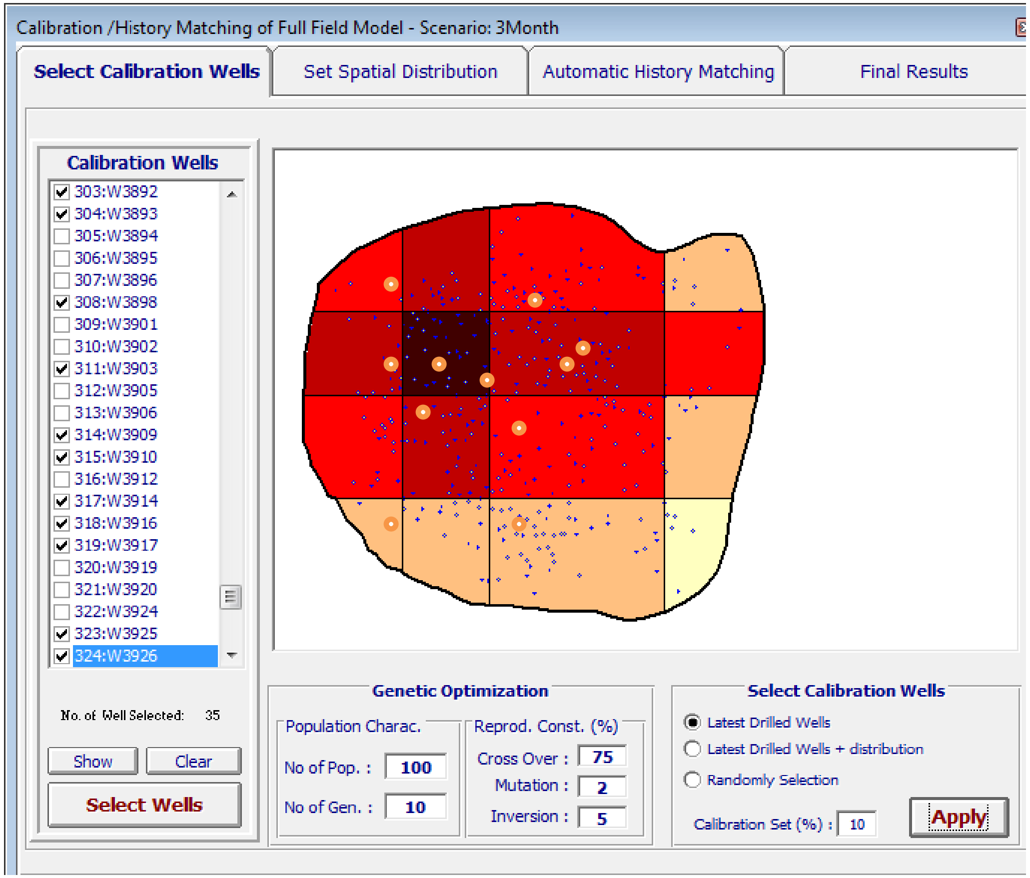
Predictive Model

- Predictive models for each well are developed based on spatio-temporal data:
  - Static and dynamic properties of offset wells.
  - Static and dynamic properties of each well being modeled.



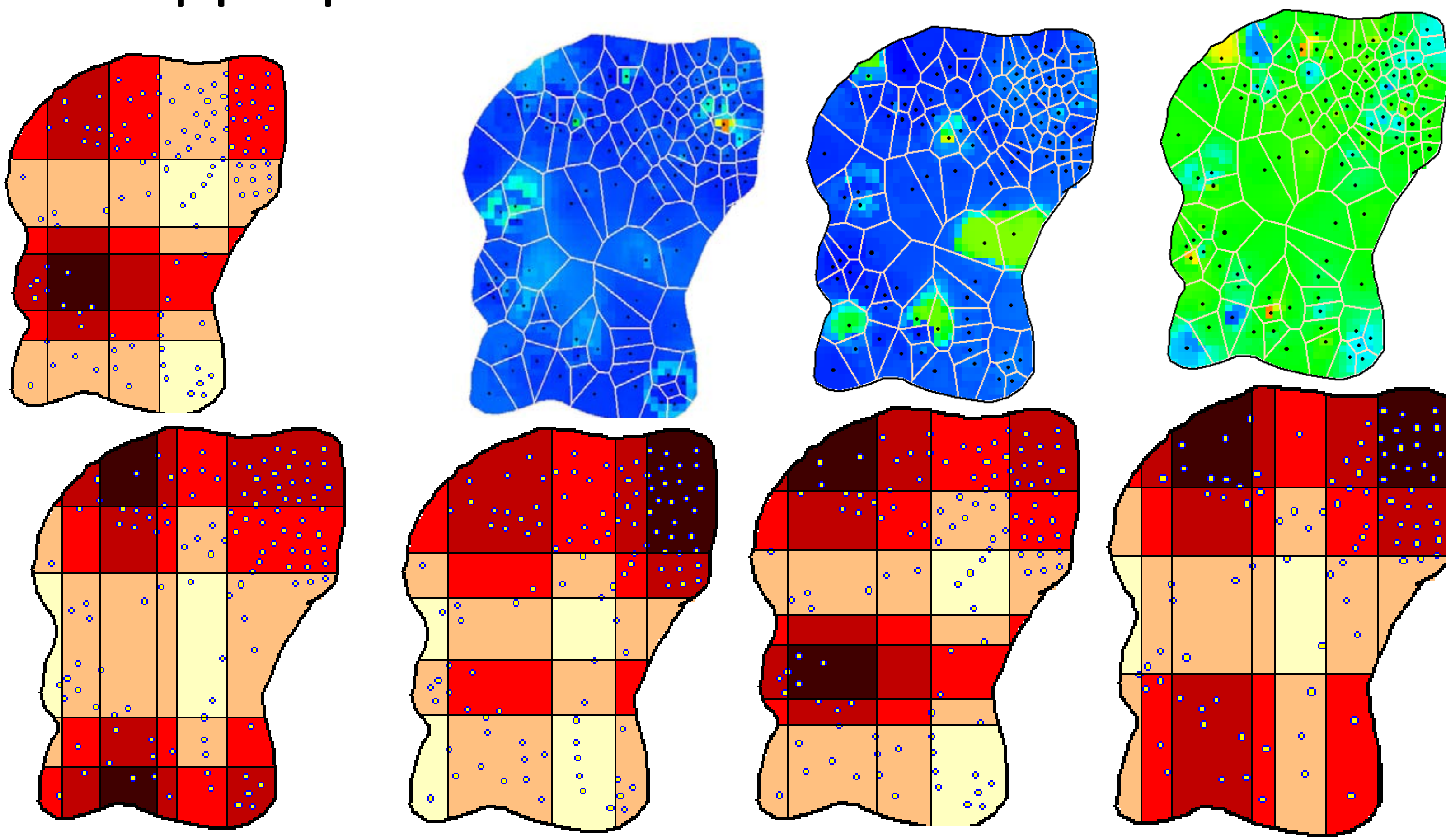
Calibration/Validation

- Latest drilled wells in the field can be selected to validate the reservoir model.

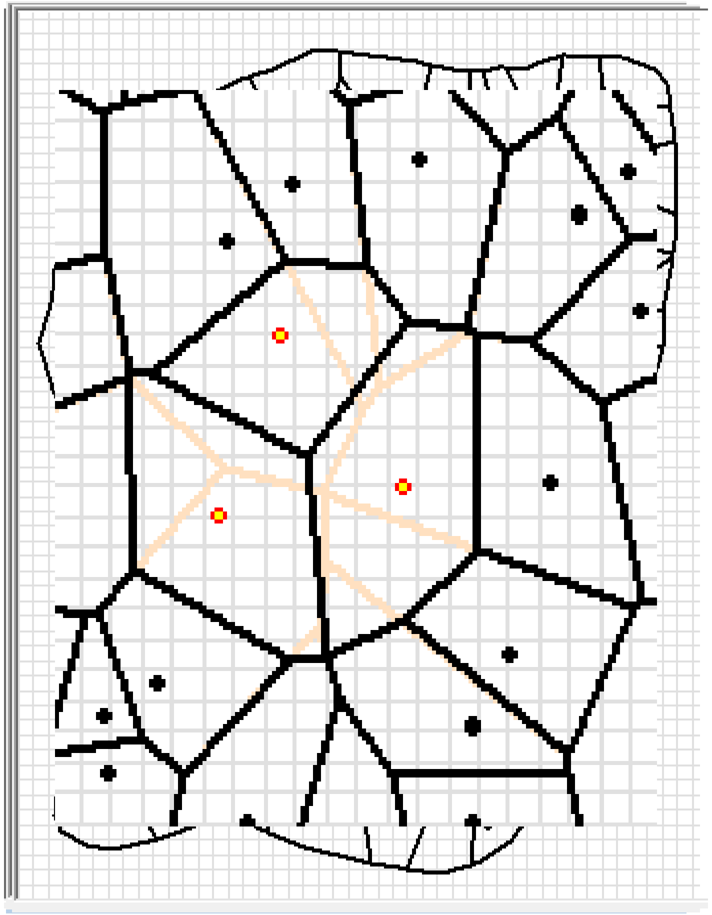


Field Development Strategies

- Using the generated maps, user will identify the most appropriate locations for infill wells.



Field Development Strategies



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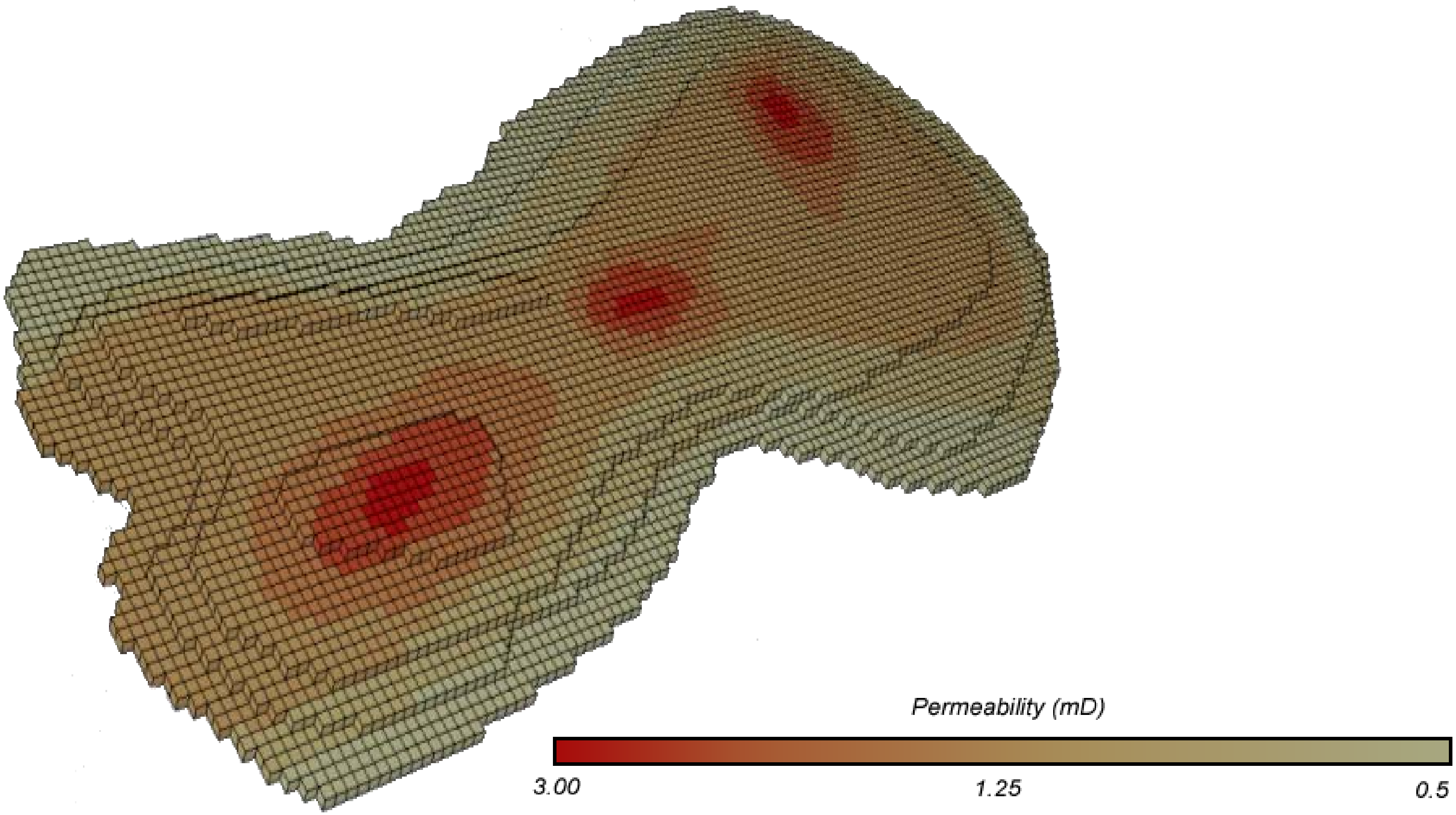
Methodology

Permeability

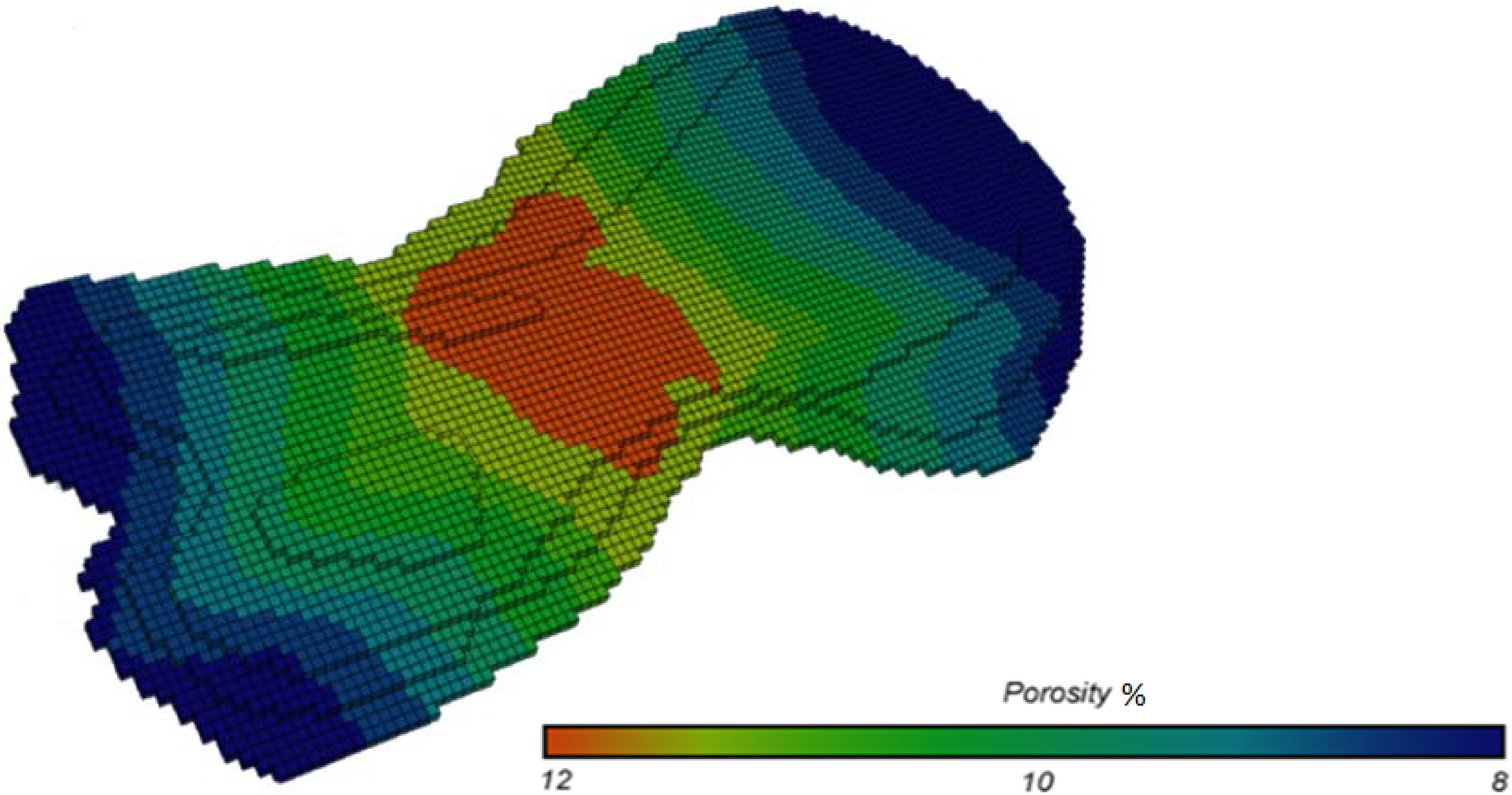
Single Layer Models



Methodology

Porosity

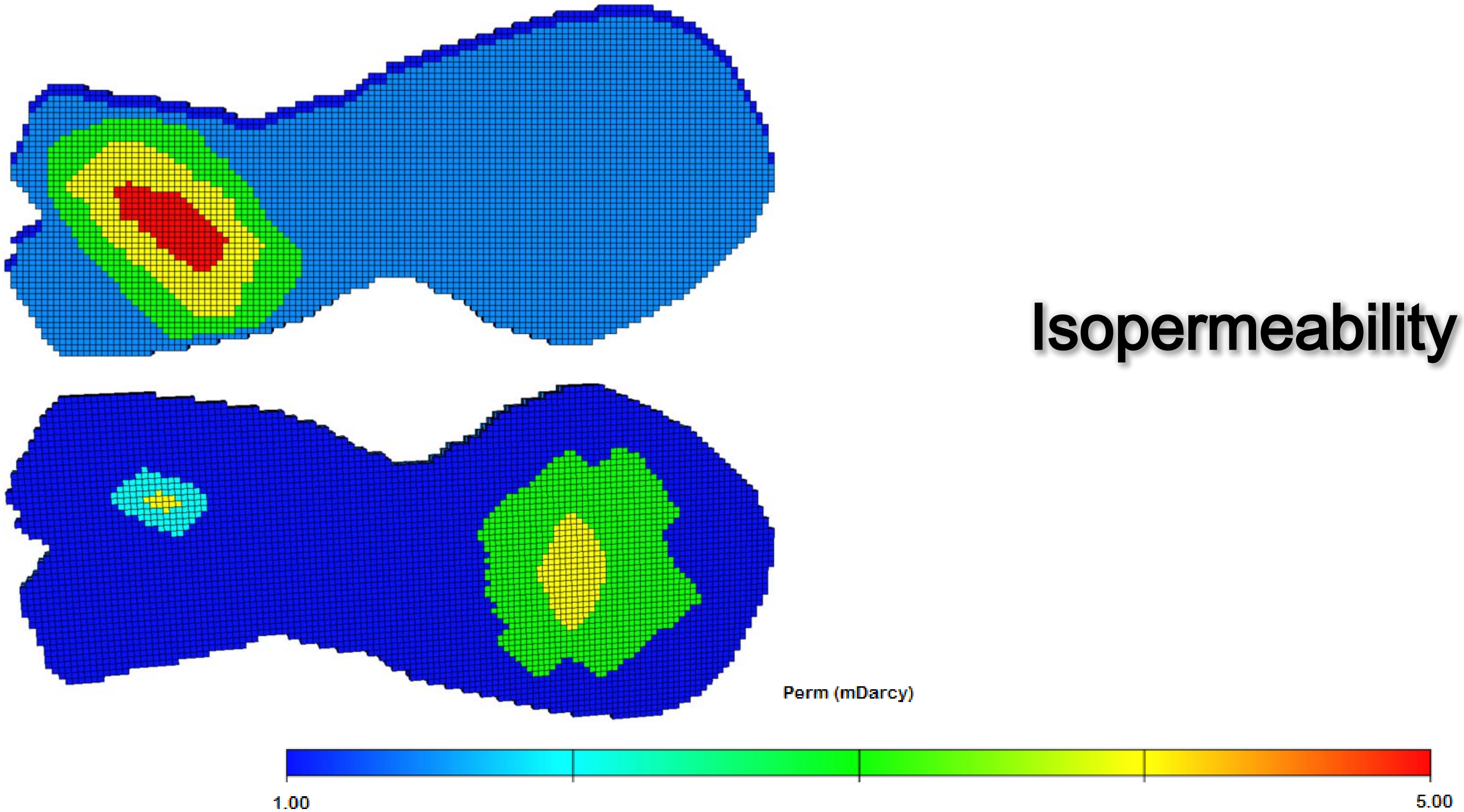
Single Layer Model



Methodology

Permeability

Two-Layer Model

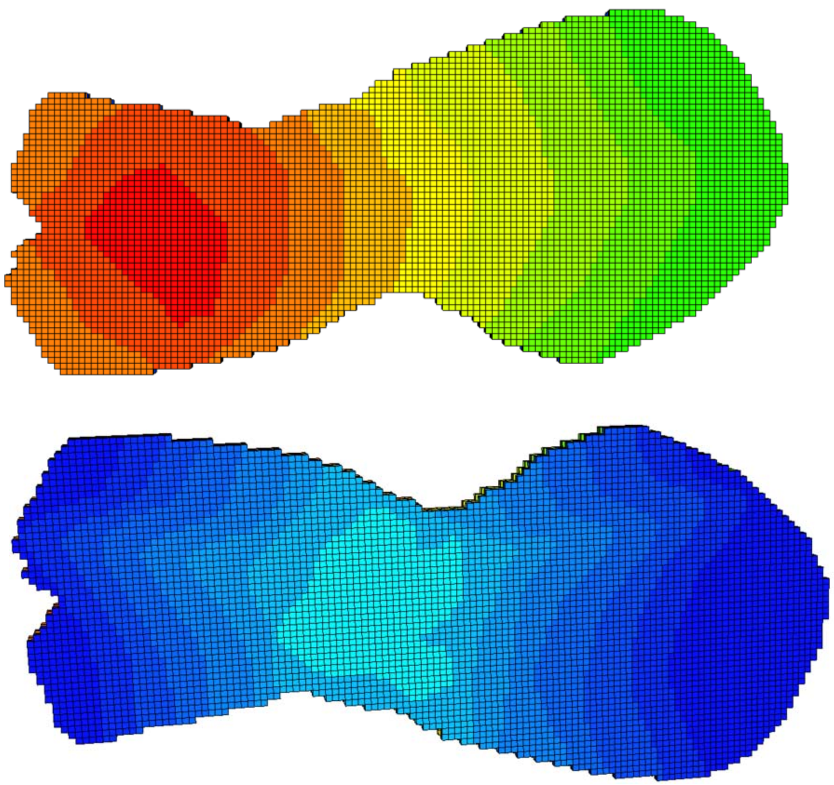


Isopermeability

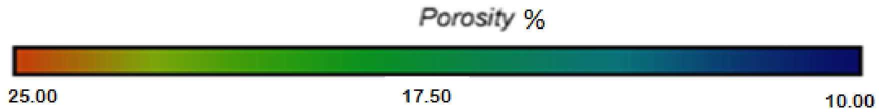
Methodology

Porosity

Two-Layer Model



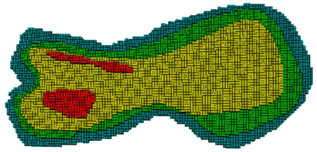
Isoporosity



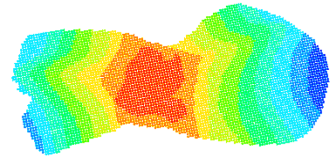
Initial Gas In Place (IGIP)

Results SLM-100

Thickness



Actual Porosity Distribution



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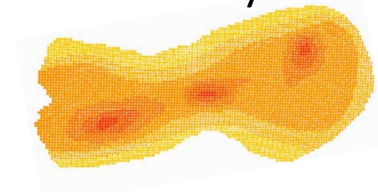
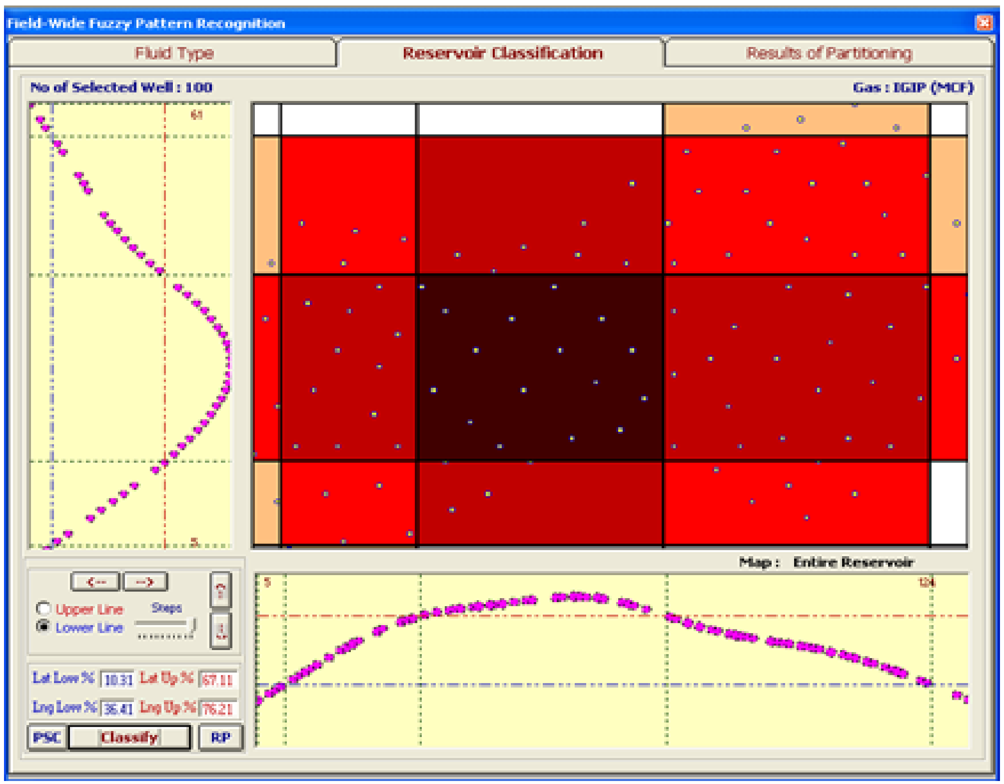
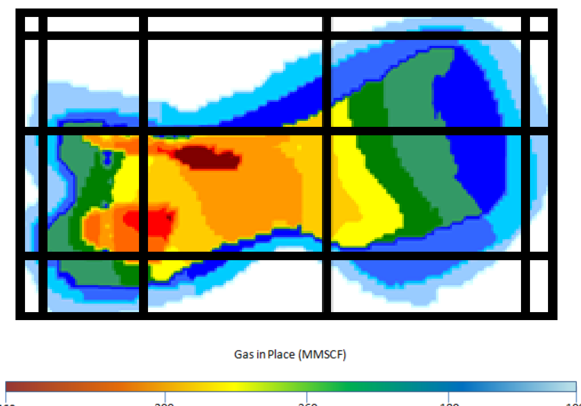


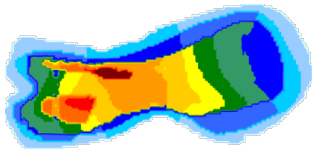




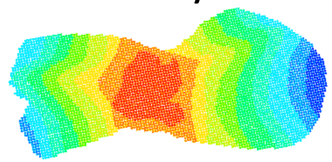
Gas in Place (MMCF)

1,357 213

IGIP



Actual Porosity Distribution



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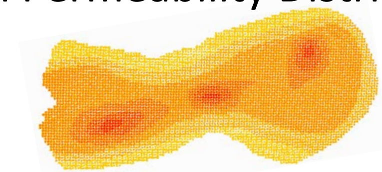
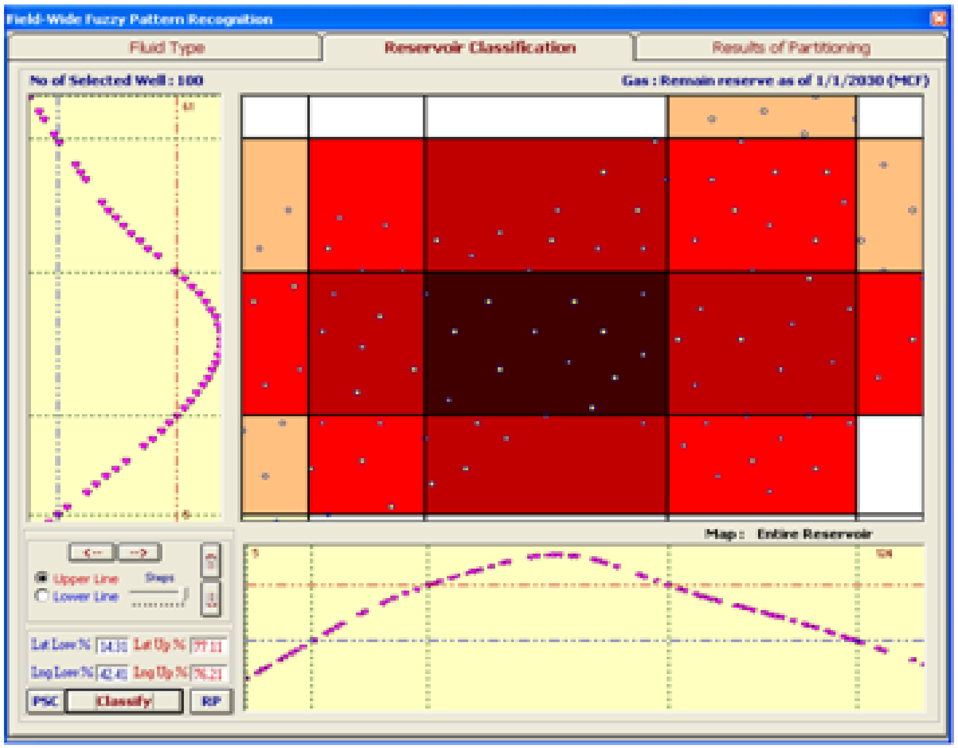
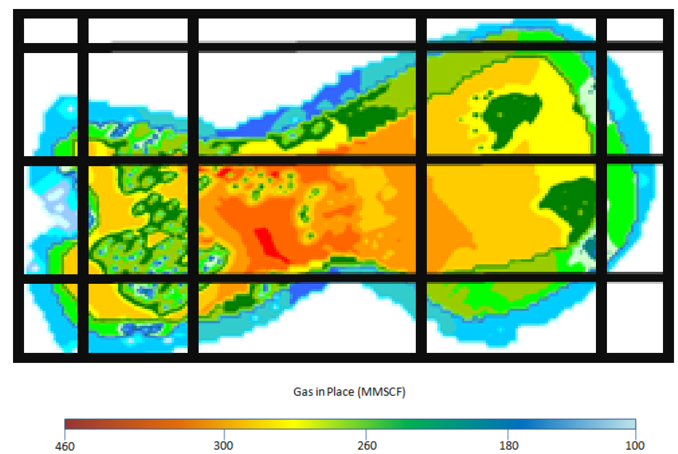


Remaining Reserves after 30 years

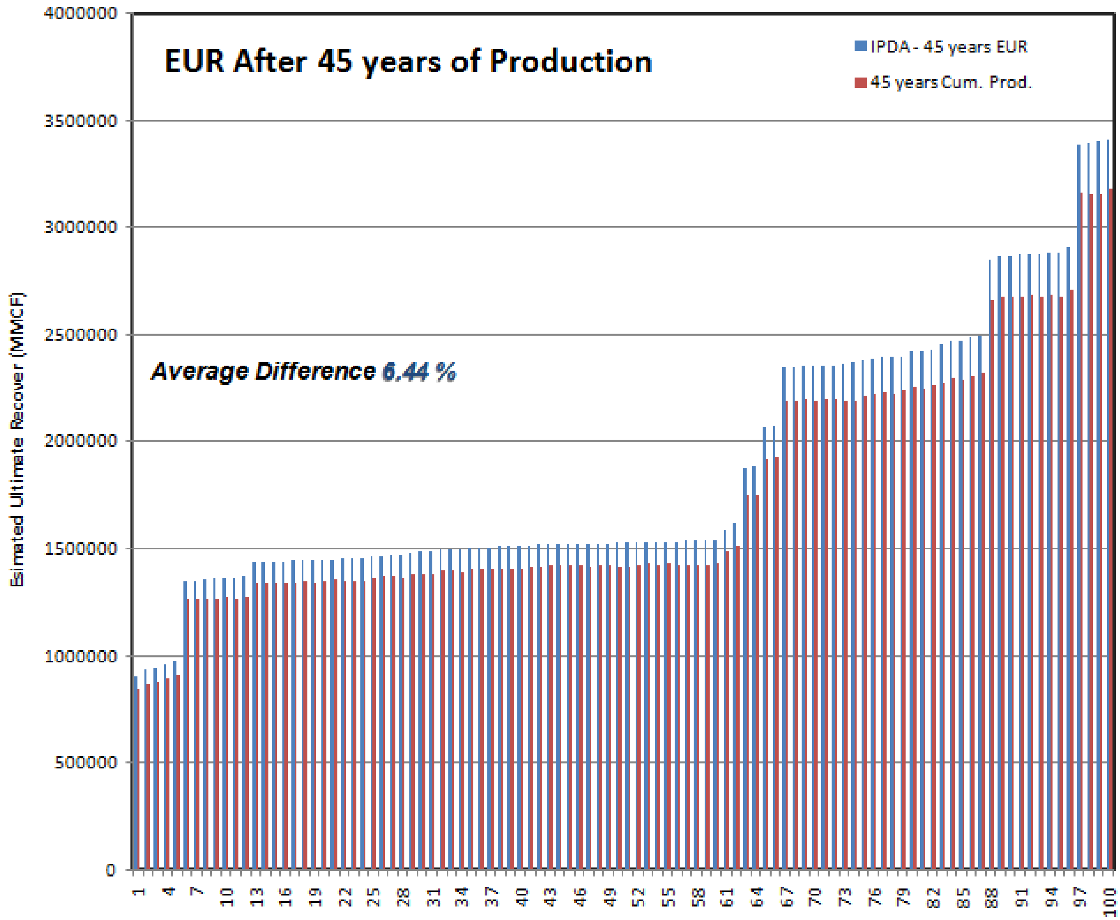
Results SLM-100



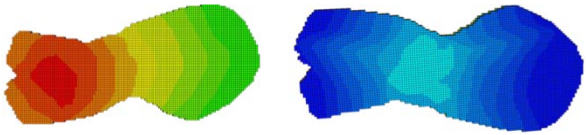


Estimated Ultimate Recovery @ 45 years

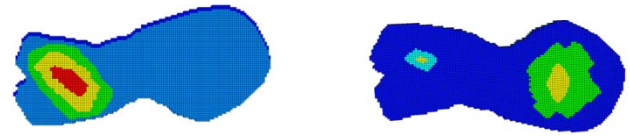
Results SLM-100



Actual Porosity Distribution

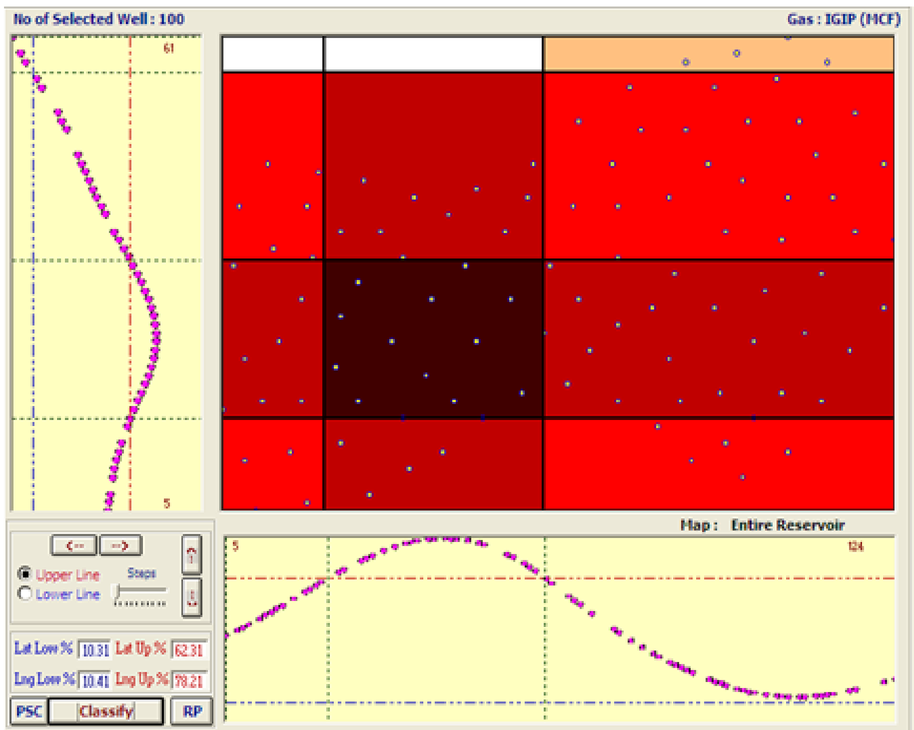


Actual Permeability Distribution

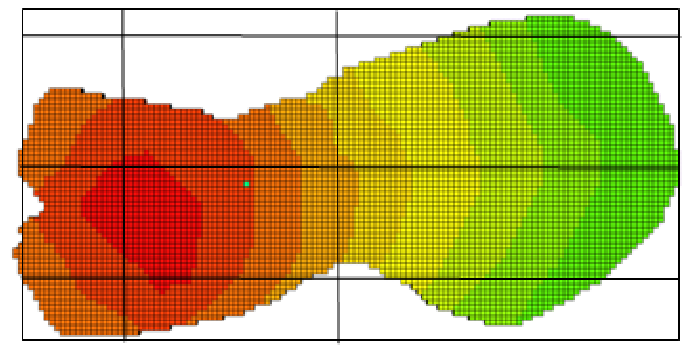


Initial Gas In Place (IGIP)

Results TLM

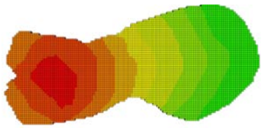


Gas in Place (MMCF)



Gas in Place (MMSCF)

IGIP



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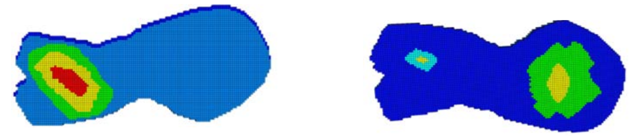
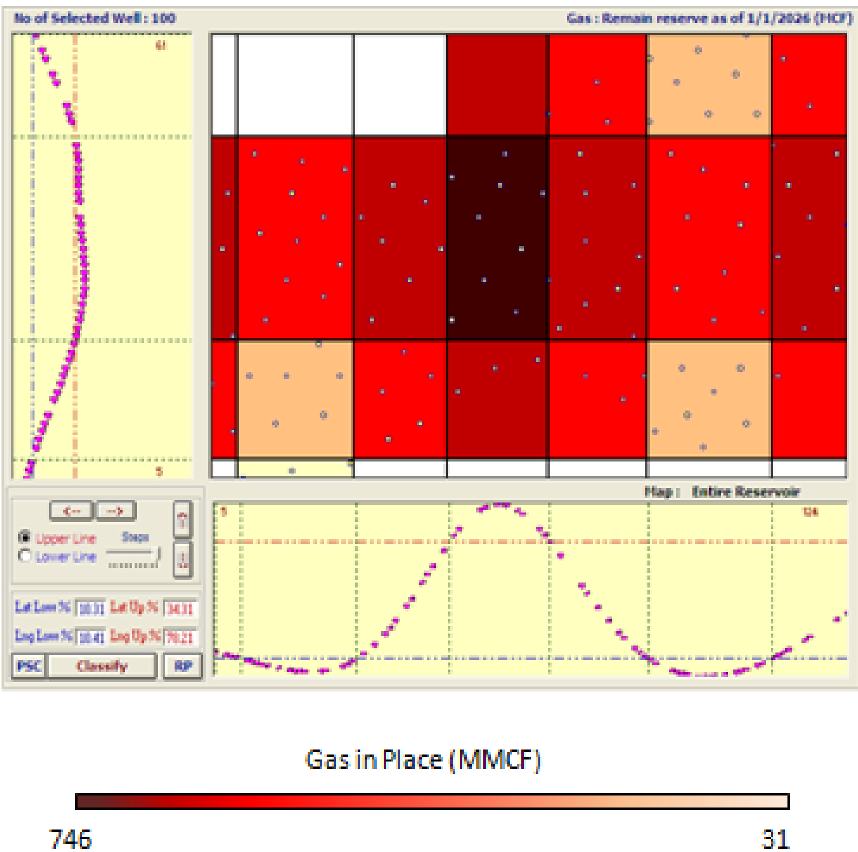
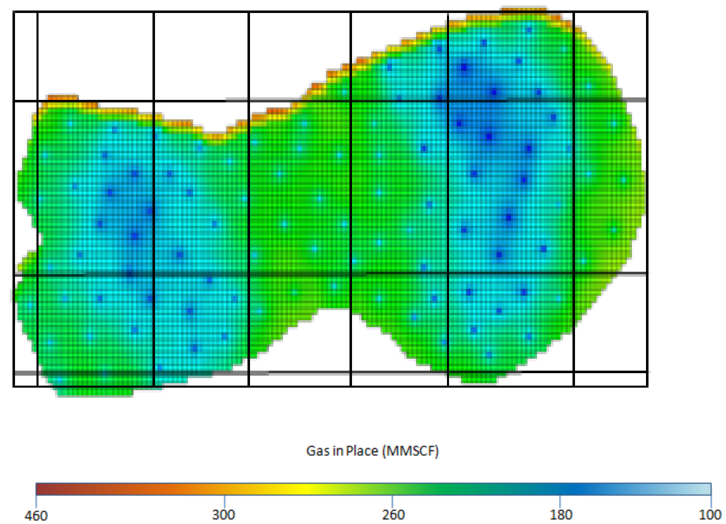


Remaining Reserves after 30 years

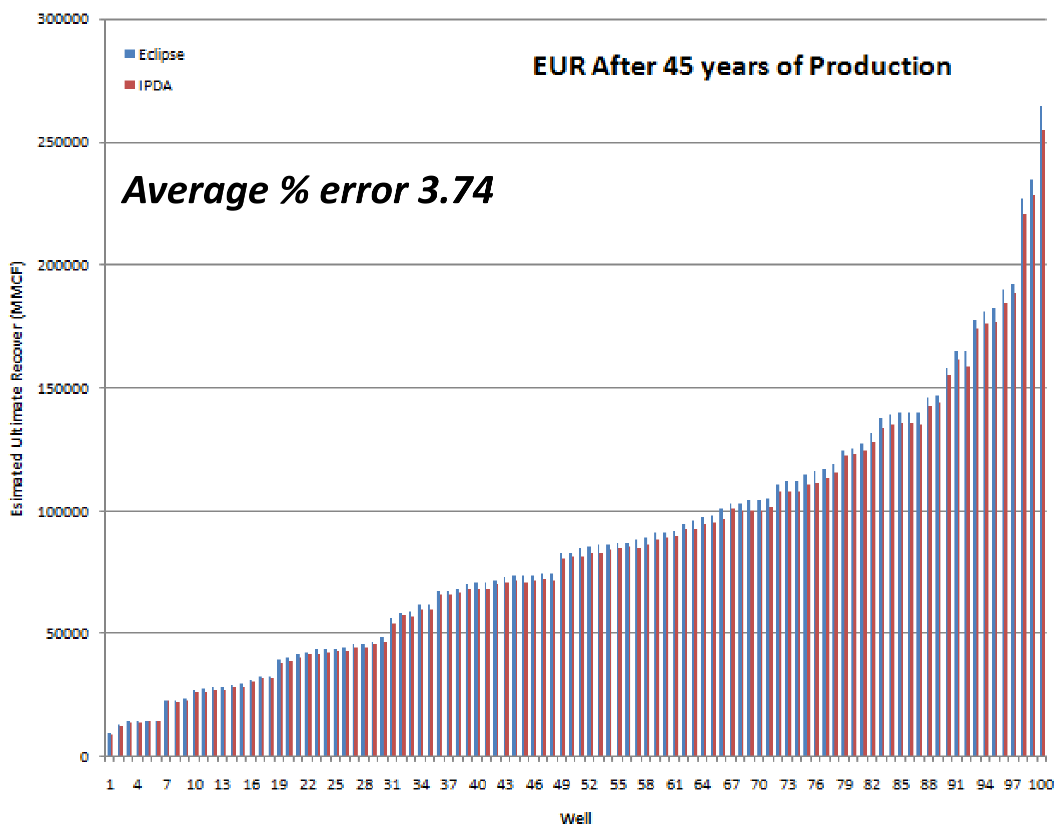
Results TLM





Estimated Ultimate Recovery @ 45 years

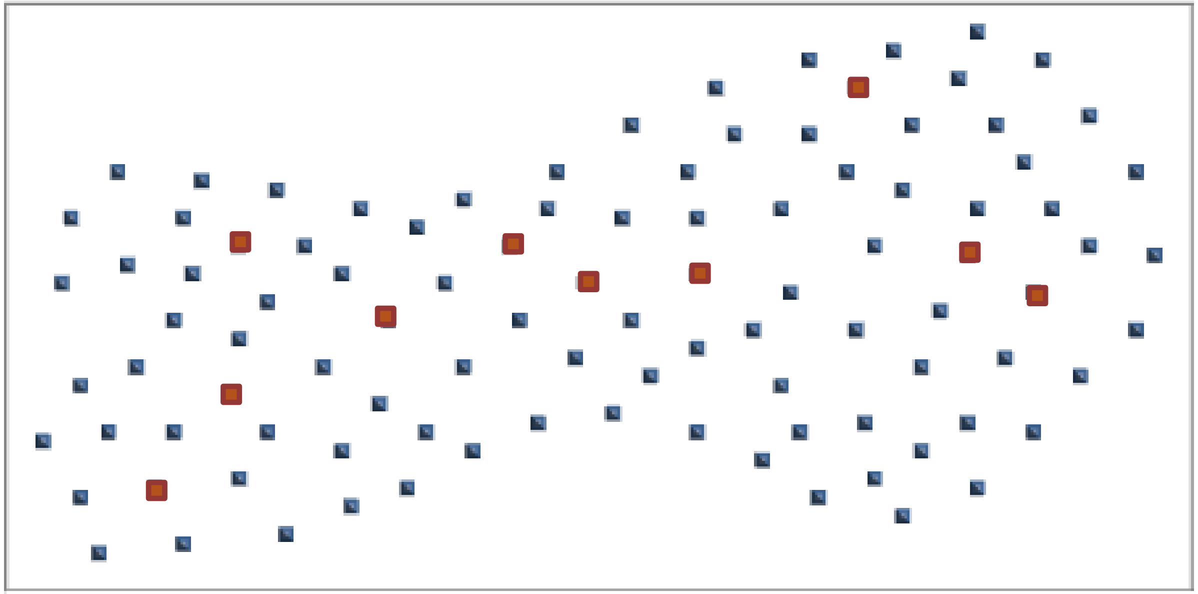
Results TLM



Select 10 wells in the reservoir and added positive skin (+4)

Model SLM 100

Under Performer Wells



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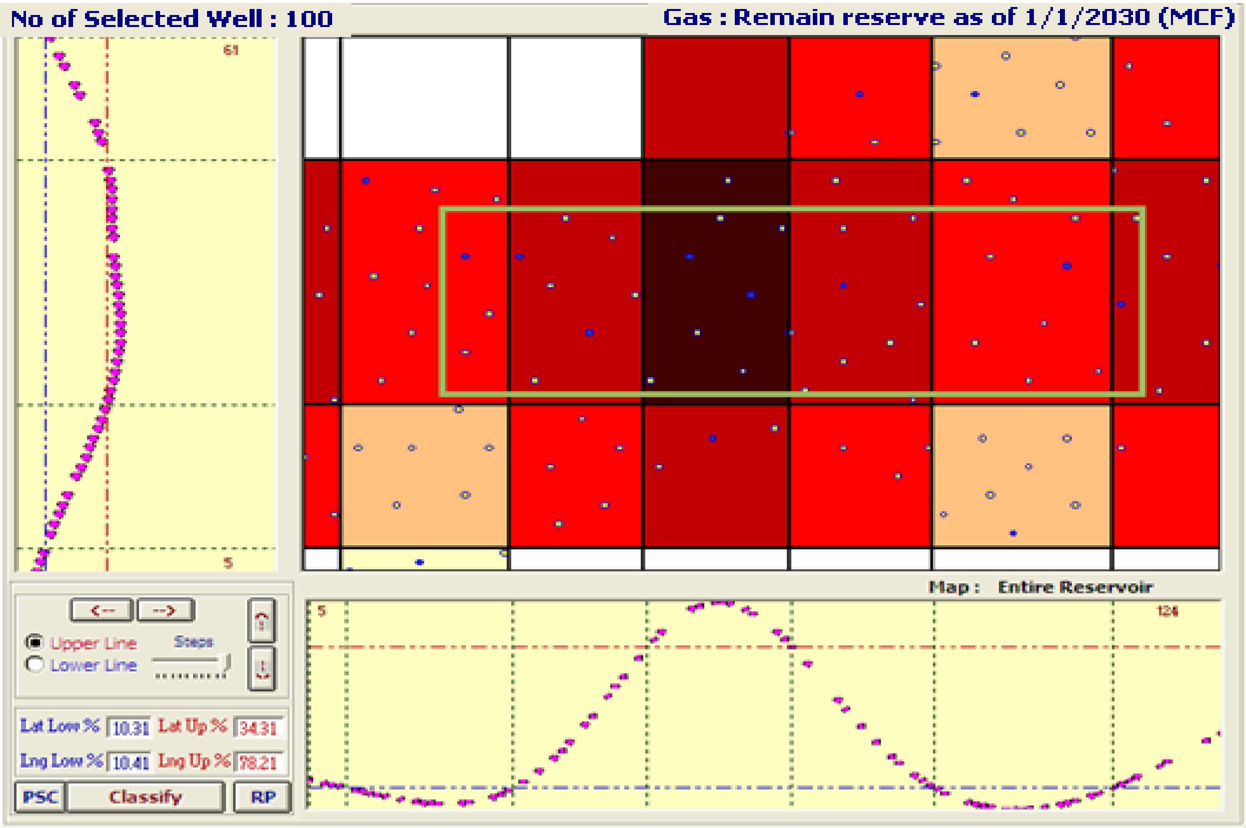
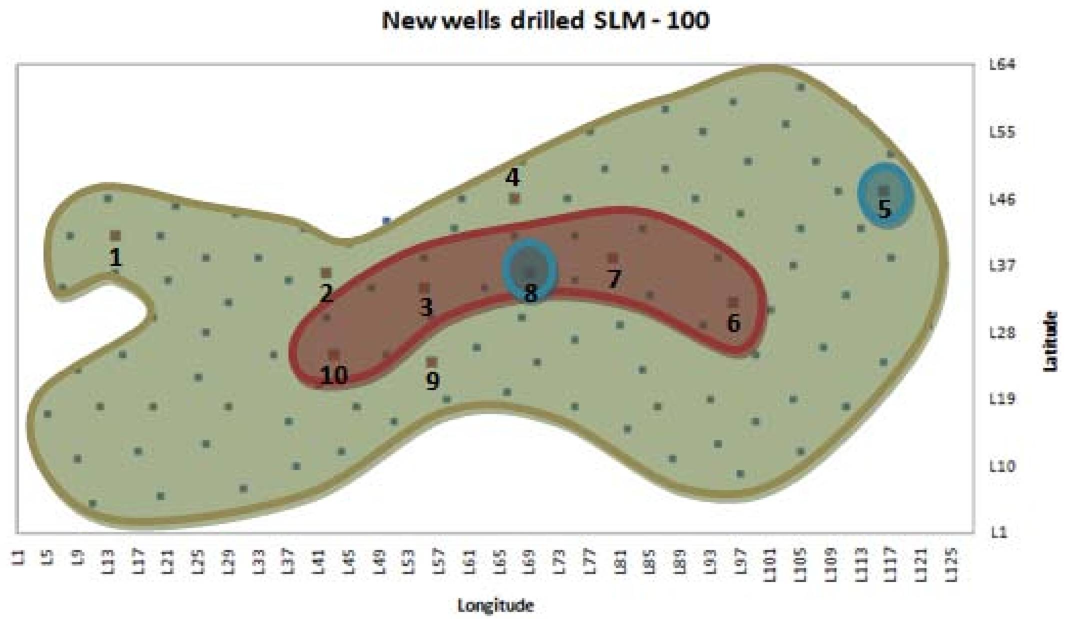


Predicting Behavior of Future Wells

Model SLM 100

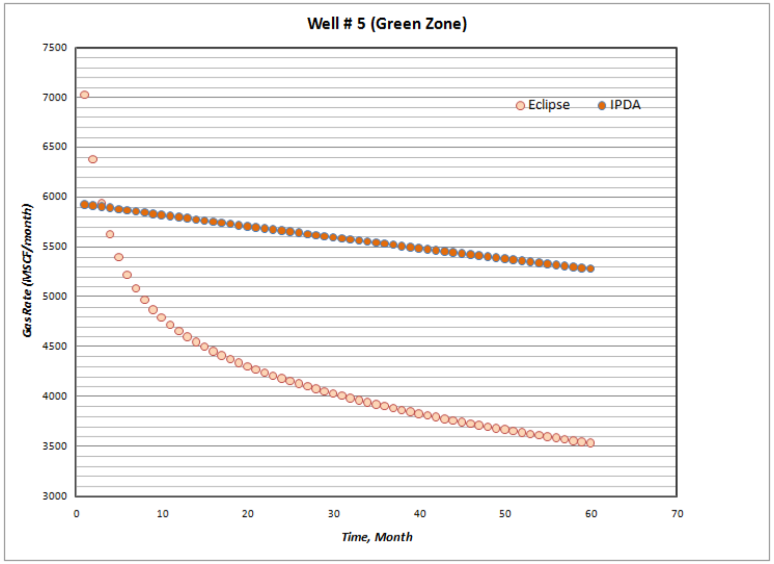
Verification Process



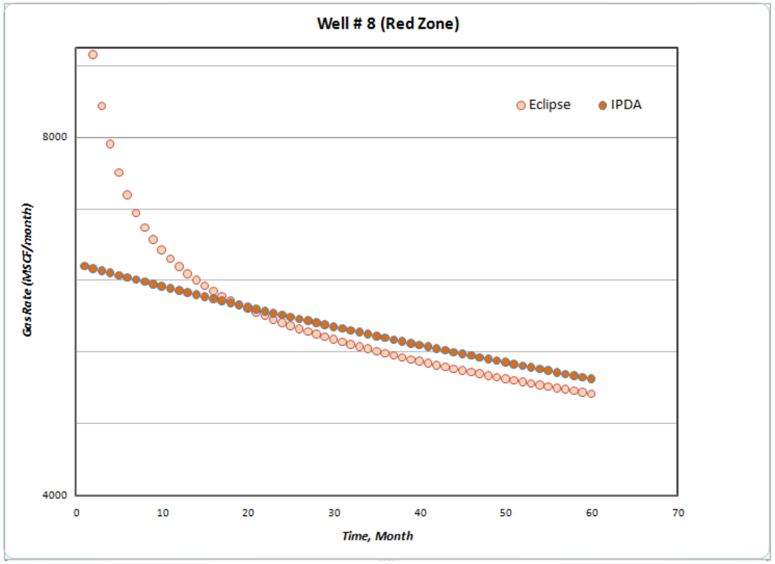
Model SLM 100

Verification Process

Close to the boundaries



Away from the boundaries



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Conclusions

- A new alternative to conventional reservoir simulation and modeling is presented.
- TDRIM attributes include:
  - Complexity (data driven)
  - Resources (time-man power- budget)
  - Data Requirement
- May be used to complement existing reservoir simulation models.

QUESTIONS?